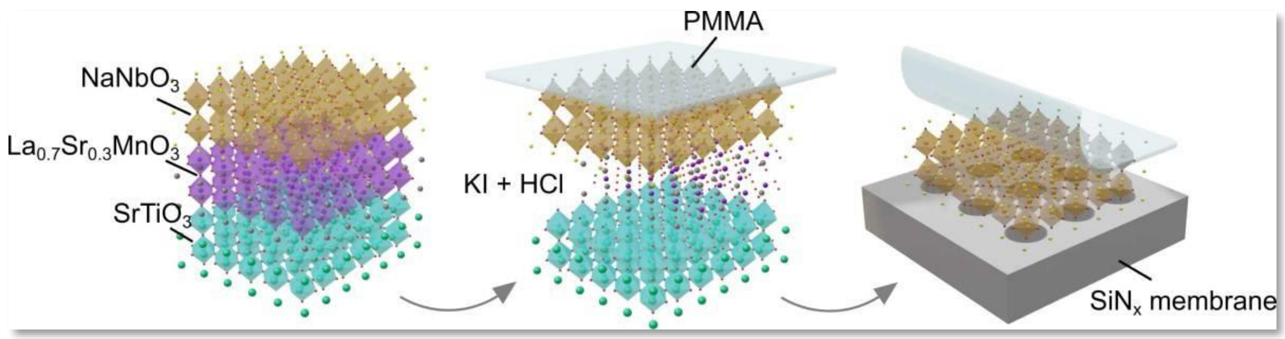
Thinner antiferroelectrics become ferroelectric

06 Mar 2023 Isabelle Dumé



Changing phase: antiferroelectric-to-ferroelectric phase transition. (Courtesy: *Advanced Materials* CC BY 4.0)

Reduced beyond a certain size, antiferroelectric materials become ferroelectric. This new result, from researchers in the US and France, shows that size reduction could be used to turn on unexpected properties in oxide materials and indeed a range of other technologically important systems.

Antiferroelectric materials consist of regularly repeating units, each of which has an electric dipole – a positive charge paired with a negative one. These dipoles alternate through the crystalline structure of the material and such regular spacing means that antiferroelectrics have zero net polarization on the macroscale.

While ferroelectrics are also crystalline, they usually have two stable states with two equal and opposite electric polarizations. This means the dipoles in the repeating units all point in the same direction. The polarization of the dipoles in a ferroelectric material can also be reversed by an applying an electric field.

Thanks to these electrical properties, antiferroelectrics can be used in high-density energy storage applications while ferroelectrics are good for memory storage.

Directly probing the size-driven phase transition

In their work, which is detailed in *Advanced Materials*, the researchers led by Ruijuan Xu of North Carolina University studied the antiferroelectric sodium niobite ($NaNbO_3$). While

previous theoretical studies predicted that there should be an antiferroelectric-to-ferroelectric phase transition as this material was made thinner, such a size effect had not been verified experimentally. This was because it was difficult to completely separate the effect from other phenomena, such as the strain arising from the lattice mismatch between the material film and the substrate it had been grown on.

To overcome this problem, Xu and colleagues lifted the film off the substrate by introducing a sacrificial layer (that they then dissolved) between the two materials. This method allowed them to minimize the substrate effect and directly probe the size-driven phase transition in the antiferroelectric material.

The researchers found that when the $NaNbO_3$ films were thinner than 40 nm, they became completely ferroelectric, and that between 40 nm to 164 nm, the material contains ferroelectric phases in some regions and antiferroelectric phases in others.

Exciting discovery

“One of the exciting things we found was that when the thin films were in the range where there were both ferroelectric and antiferroelectric regions, we could make the antiferroelectric regions ferroelectric by applying an electric field,” says Xu. “And this change was not reversible. In other words, we could make the thin film completely ferroelectric at thicknesses of up to 164 nm.”

According to the researchers, the phase changes they observed in very thin antiferroelectric materials come about as the surface of the films distorts. Instabilities at the surface ripple throughout the material – something that is not possible when the material is thicker.

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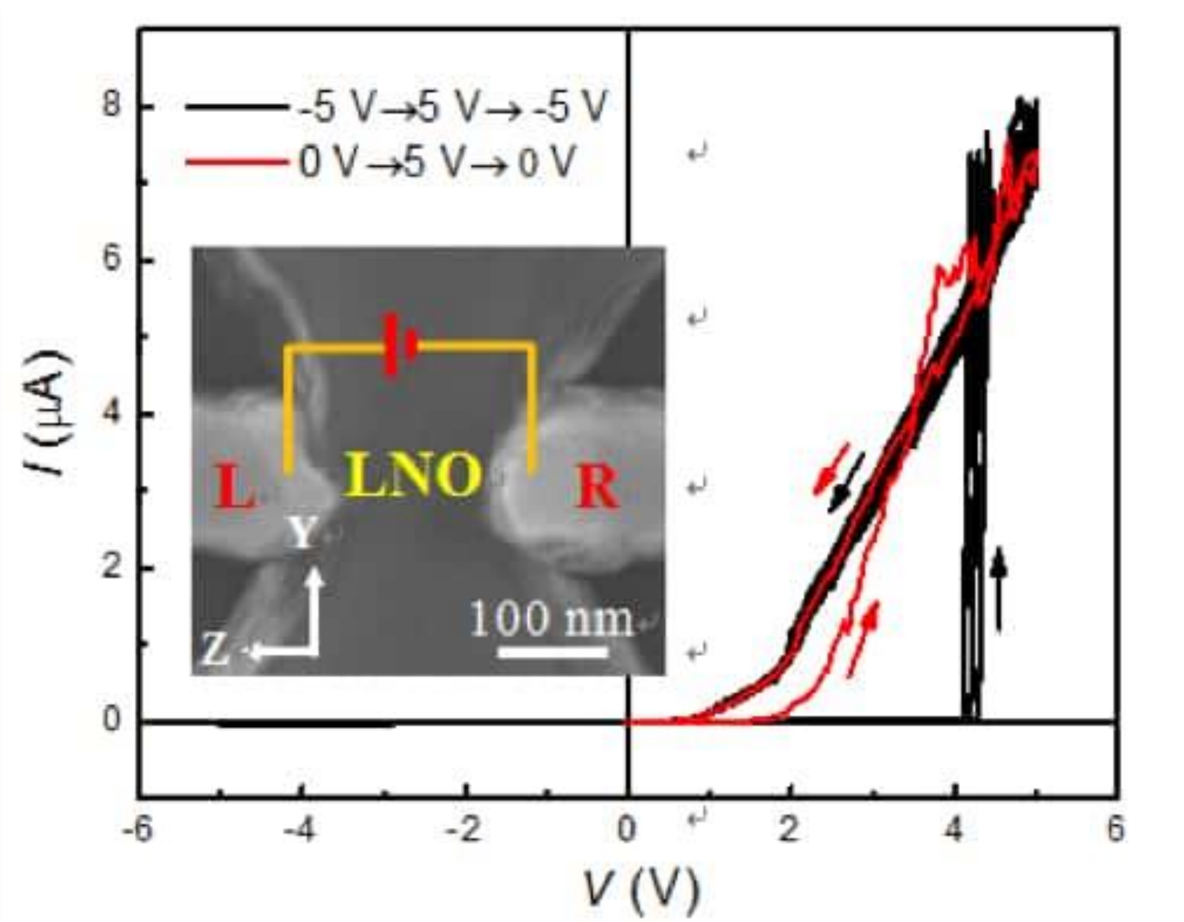

Ferroelectric domain wall diodes get flexible

"Our work shows that these size effects can be used as an effective tuning knob to turn on unexpected properties in oxide materials," Xu tells *Physics World*. "We expect to discover more emergent phenomena in other oxide membrane systems using these effects."

The researchers say they are working on fabricating $NaNbO_3$ thin-film based devices to probe the electrical properties on the macroscale. "We hope to be able to manipulate the phase stability and obtain enhanced electrical properties in these devices, which will be useful for potential applications," says Xu.